Material response reconstruction of ablative TPS using accurate boundary layer modeling

Completed Technology Project (2016 - 2020)

Project Introduction

For hypersonic atmospheric entry missions, charring ablators are often used. These materials are made of non-pyrolyzing matrices (carbon, ceramic, etc.) combined with pyrolyzing materials (phenolic, silicon resin). Pyrolysis is the process in which the polymer gradually carbonizes at high temperature, losing mass and generating pyrolysis gas. Once generated inside the matrix, the gas is expelled at the surface, changing the chemical composition of the boundary layer and influencing the thermal conductivity. The material models currently used for designing AVCOAT thermal protection systems (TPS) are based on models that were designed during the Apollo era. Although they have been updated to better replicate the behavior of modern-day AVCOAT, such as that used on Orion, they remain very similar to the original. Although these models have been adequate in providing analyses leading to successful missions, they they fail to account for specific physical processes; the results therefore lack accuracy, leading to higher safety margins for TPS.. The current proposal aims at using a statistical approach to redesign, from the ground up, the AVCOAT material model currently used by NASA. Using uncertainty analysis, the extensive AVCOAT arc-jet data will be thoroughly analyzed, and used to estimate the best simulation parameters. This new material model will then be applied to the EFT-1 flight data, and its accuracy will be assessed. As a second task, a new integrated modeling approach will be developed and tested. Contrary to the state-of-the-art which consist of coupling (loosely or not) a CFD code to a Material Response (MR) code, the new method proposes to solve the whole domain using one general set of equations for both the flow field and the porous ablator. This approach has the advantage of effectively removing all boundary layer assumption currently used in aerothermal boundary conditions by letting the code calculate the surface fluxes intrinsically, and not by imposing approximate surface balance equations.

Anticipated Benefits

Contrary to the state-of-the-art which consist of coupling (loosely or not) a CFD code to a Material Response (MR) code, the new method proposes to solve the whole domain using one general set of equations for both the flow field and the porous ablator. This approach has the advantage of effectively removing all boundary layer assumption currently used in aerothermal boundary conditions by letting the code calculate the surface fluxes intrinsically, and not by imposing approximate surface balance equations.

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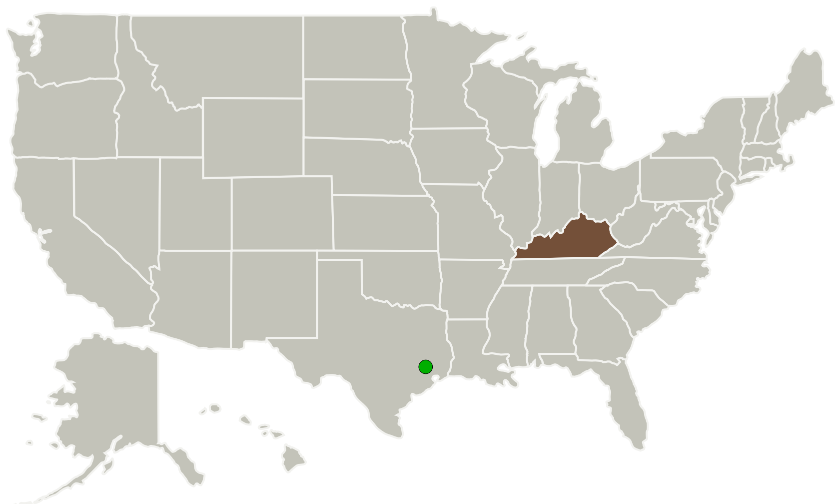
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Kentucky	Lead Organization	Academia	Lexington, Kentucky
Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas

Primary U.S. Work Locations
Kentucky

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Kentucky

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

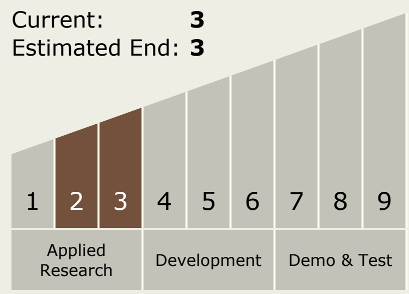
Hung D Nguyen

Principal Investigator:

Alexandre Martin

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  - └─ TX09.4 Vehicle Systems
    - └─ TX09.4.5 Modeling and Simulation for EDL

Target Destination

Outside the Solar System